FINAL DRAFT AET REPORT ON THE D13R4 SCENARIO
Bullets Report and Full Report
February 26, 1999

Introduction

The Alternative Evaluation Team for the C&SF Restudy conducted a preliminary evaluation of the D13R4 scenario during a meeting of the full AET on 20 January 1999. The objective of this modeling exercise was to determine the feasibility of improving D13R, by capturing additional surplus water from the amount discharged to tide each year, and of conveying that “new” water (plus redistributing excessive water in the Water Conservation Areas) to better meet performance targets in the natural system. Scenarios designed to convey urban runoff water into the natural system have not previously been considered during the lengthy AET/ADT plan formulation process. The D13R4 scenario reported on here was clearly the most successful of four scenarios (R1–R4) that were developed during an intensive, multi-agency planning and modeling process, which began in November 1998.

The AET found that the overall performance of Scenario D13R4, as modeled on 13-14 January, included both gains and losses when measured against the 1995 base, 2050 base, and D13R conditions. D13R4 captured an average of 253,000 acre feet/year of new water for the natural system from Palm Beach and Broward counties. This new water, combined with excessive water from the WCAs, provided an average of 271,000 acre feet of new water each year to Everglades National Park and an average of 77,000 acre feet of new water to Biscayne Bay each year. The increased annual mean flows to the park and Biscayne Bay are expected to produce substantial improvements towards meeting the hydrological performance targets for these two areas. Although D13R4 also provided modest improvements in northeast WCA 3A and northeast 2B, by reducing the number of undesirable high water events in these two subregions, this scenario increased the number of undesirable high water events in WCAs 2A and 3B to a level greater than that predicted for the two base conditions. D13R4 also created undesirable increases in the depth and duration of flooding in the Pennsuco wetlands. By delivering urban water to the natural system, this scenario raises a number of new water quality questions.

Table 1. Details of Flows to Tide in Thousand Acre Feet/year (captured)

Canal/Structure	95BS	D13R	D13R4	D13R-D13R4
C-51 @ S-155	375	173	74	+99
C-16 @ S-41	90	31	13	+18
C-15 @ S-40	94	33	13	+20
Hillsboro @ G-56	125	28	29	-1
PBC subtotal	**684**	**265**	**129**	**+136**
C-14 @ S-37A	106	97	49	+48
C-13 @ S-36	53	25	15	+10
NNR @ G-54	69	99	40	+59
Broward subtotal	**228**	**221**	**104**	**+117**

The AET recognizes that much new information regarding the potential performance of D13R was gained during the modeling of the four scenarios R1-R4 of D13R. The hydrological responses during the modeling of these four scenarios convincingly demonstrated the operational flexibility of D13R, and offers encouraging documentation that additional improvements can be achieved during the detailed planning phases of the restoration program. The AET recommended that the specific features of D13R4 that allowed for the capture and conveyance of substantial amounts of new water for the natural system be incorporated into the Recommended Plan, D13R, contingent upon (1) finding ways to reduce the number of damaging high water events in WCA 2A and 3B to a level at or below the level predicted for D13R and (2) adequately treating the stormwater runoff from the C-51 east/C-13/14 basins directed into the Everglades Protection Area to meet all state and federal water quality standards to enable ecological restoration to be achieved. Excessive high water events in the Pennsuco wetlands also should be moderated. It was agreed that these concerns can best be resolved during the finer scale modeling and planning which will occur as a part of detail design work. The addition of these features should allow greater operational flexibility during future efforts to improve the overall performance of D13R. An issue paper may be required from the Restudy's water quality team, to more fully explore the questions being raised by the use of urban water to meet natural system targets in Everglades National Park.

AET Subregional "Bullet" Summary Evaluations of D13R4:

Water Quality

For the first time, 253,000 acre feet/year of urban runoff was captured, treated, and sent into the natural system to augment flows to Everglades National Park and Biscayne Bay, raising the following questions:

- D13R4 assumes that the technology exists for treating urban stormwater for a whole suite of water quality parameters beyond nutrients.

- There may not be sufficient land available to adequately treat the volume of wet season runoff this scenario requires.

- Due to complex pollutant loads associated with urban runoff, future permitting of new discharges of treated urban runoff to Outstanding Florida Waters (ENP & Biscayne Bay) is expected to be difficult for the responsible regulatory agencies.

- The additional treatment and routing facilities add a new layer of complexity to the sequencing of the implementation plan

- Benefits of the new water will not be seen until all necessary water treatment components are up and running.

Total System

- Connectivity was similar to D13R except for an increase in extreme depth differences between WCA-2 and WCA-3.

- Sheetflow in WCA-2B showed an NSM-like pattern for the first time. Flows also improved across Tamiami Trail east of L-67 and the eastern part of Everglades National Park.

- Fragmentation was the same as D13R. No additional canals and levees were removed within the natural system.

Northern Estuaries

- **Caloosahatchee**: No change.

- **St Lucie Estuary**: One additional discharge event over the 31-year period of record.

- **Lake Worth**: Far fewer adverse discharges of fresh water.

Lake Okeechobee

- No change.

Lower East Coast

- Water supply performance is the same as D13R except there are two additional months in Broward County of low water conditions along the coast in the 31-year period of record.

Northern and Central Everglades

- Eastern and northeastern WCA-3A and WCA-2B are better, but still far from the NSM envelope. New problems arose in WCA-2A and WCA-3B. The modest benefits were seen in some of the more degraded areas but serious problems developed in more pristine parts of the system.

- Southern WCA-2A: Much worse than all plans and base conditions in extreme high water and extreme low water conditions. Increasing the flows through WCA-2A during the wet season only raised depths without helping increase hydroperiods into the dry season.

- WCA-2B: Extreme lows improved in the northern part, extreme highs increased slightly in some areas and there were substantial improvements in hydroperiod. Part of WCA-2B is approaching NSM-like conditions; the rest is still outside the NSM envelope.

- Eastern WCA-3A: General improvement in extreme high water conditions, particularly the area east of the Miami Canal. South of Alligator Alley, high water conditions are still poor. Extreme low water conditions did not change. The area is still outside the NSM envelope for both high and low water extremes.

- WCA-3B: High water conditions worsened. In the west, they are worse than the 1995 base, in the east they are worse than both bases. Both the frequency and depths of high events are far outside the NSM envelope for any NSM landscape. This is a problem must be resolved.

Pennsuco

- Both water levels and hydroperiods worsened relative to D13R. Water levels in the Pennsuco increased sufficiently higher to present a threat to tree islands.

Biscayne Bay

- An additional 77,000 acre feet/year of water was sent to Biscayne Bay, greatly improving conditions. Flows could be balanced better between parts of the bay but there is obviously the flexibility within the plan to do so.

- With some minor redirection of wet season flows between Central and South Biscayne Bay, D13R4 could meet targets in Central and South Biscayne Bay without reuse water from the proposed South Miami-Dade coastal reuse facility.

Model Lands

- D13R4 slightly increases water levels in coastal wetlands, particularly east of U.S. 1 during the dry season.

Big Cypress

No change from D13R. Some water that used to flow west toward Roberts Lake Strand under NSM conditions still tends to move east as it did in D13R, apparently because of topography differences between NSM and SFWMM in the jetport vicinity. This is not good, but not a major problem.

Southern Everglades

- D13R4 delivered 271,000 acre feet/year of "new" water to Everglades National Park and performance measures closely approached targets for Shark River Slough and the Florida Bay coastal basins and exceeded targets in Rockland Marl Marsh. More detailed AET analyses of D13R4 for the southern Everglades will be available the week ending January 29, 1999.

- Endorsement of D13R4 by the AET regarding benefits to the southern Everglades should be strongly conditional on reversing potentially damaging effects to WCA-2A and WCA-3B and on providing adequate water quality treatment during detailed design and modeling.

Endangered Species

- Preliminary analysis shows no change to Cape Sable Seaside Sparrow, maybe a slight improvement for eastern populations.

- Improved conditions for wood storks, crocodiles, and manatees.

- ATLSS modeling results may show some snail kite concerns.

Uncertainties

- The NSM topography in NE Shark River Slough is assumed to be the same as current topography, although recent data collected by EPA scientists indicate that substantial soil subsidence has occurred since the 1940's. This discrepancy in the topographic model very likely affects the depth targets for NESS. If the NSM topography were altered to have comparable soil subsidence assumptions for WCA-3B north of Tamiami Trail and NESS south of Tamiami Trail, then target depths in NESS would probably be shallower, less water will be needed to meet those targets, and excess depths in WCA-3B would be reduced.

FULL AET REPORT ON D13R4

Water Quality

Introduction

The Water Quality Sub-team of the Restudy AET met by teleconference on Wednesday, January 27, 1999 to review Scenario D13R4 and to discuss comments and recommendations on the new scenario to the AET and the Restudy Team. The following persons participated in the teleconference: Eric Hughes and Dan Scheidt (USEPA); Bill Walker (consultant, DOI); Ken Tarboton, Tom Fontaine, Max Day, Jeff Needle, Siaka Kone, Zhenquan Chen, and Maxine Cheeseman (SFWMD); Betty Grizzle (USFWS); Nancy Gassman (Broward Co. DNRP); Mike Zimmerman and Sarah Bellmund (ENP); Herb Zebuth and Eric Bush (FDEP); and, Jim Riley (USACE).

Scenario D13R4 captures additional stormwater runoff in developed areas of Palm Beach and Broward County canals currently discharging to tide in Alternative D13R (the alternative plan selected by the Restudy Team), diverting it to the Water Conservation Areas. The purpose of the scenario was to increase overland flows into Everglades National Park and surface water flows discharged to Biscayne Bay. To accomplish this, C-51 Canal, C-15, C-16, Hillsboro Canal, C-13 Canal, C-14 Canal, and North New River basin runoff is routed (via pumps and other structural modifications) to storage components created by Alternative D13R and discharged to WCA-2A, Biscayne Bay, and Everglades National Park. A more detailed description of Scenario D13R4 is accessible via the Restudy web site, www.restudy.org.

Performance Based Comments

The effects of Scenario D13R4 on phosphorus loads and concentrations in the Everglades Protection Area can be modeled with SFWMD's Everglades Water Quality (phosphorus) Model (EWQM); however, the model had not yet been run for the scenario at the time of this writing. It should be noted that one of the Water Quality Team's previously agreed upon performance indicators for the EWQM was structural phosphorus loads discharged into the Everglades Protection Area. To meet the water quality requirements of the Everglades Forever Act, structural discharges to the Everglades Protection Area for Restudy alternatives/scenarios are assumed to be at the default phosphorus concentration criterion in the EFA (10 ppb). Using the structural phosphorus load performance indicator, and considering that Scenario D13R creates a new discharge into WCA-2A (173,000 acre feet/year, 31-year average), Scenario D13R4 would rank lower (not as preferred) from a water quality perspective in terms of relative performance in WCA 2A compared to Alternative D13R. It should be further noted that the EWQM cannot simulate ppotential water quality impacts in urban areas east of the WCAs.

The Everglades Landscape Model (ELM) would also be useful for modeling water quality and ecological responses in WCA-2A.

An initial evaluation of Scenario D13R4 was conducted using water budget data from the SFWMM. 31-year average flow volumes at selected structures for the 2050 Base, Alternative D13R, and Scenario D13R4 are compared below:

Table 2

Structure(s)	50B	D13R	D13R4
Site 1 Res to WCA 2A	0	0	173
S144-145-146s		158	501
S140A	175	460	468
NLB to B Bay (comb.)	0	88	138
NLB to ENP	0	0	88
CLB to B Bay (comb.)	0	0	71
CLB to ENP	0	95	80

Legend/Notes:

1) All flow volumes indicated are 31-year averages, in k ac. ft.
2) S144-145-146s are existing structures discharging from WCA-2A into WCA-2B
3) S140A discharges into NW WCA-3A; wq treatment via ECP/Non-ECP facilities
4) NLB = North Lake Belt Storage Area
5) B Bay = Biscayne Bay
6) CLB = Central Lake Belt Storage Area
7) ENP = Everglades National Park

Using water quality data from the SFWMD and Palm Beach and Broward County monitoring programs, mean phosphorus concentrations were determined by Dr. William Walker using an urban land use model for the basins contributing runoff captured in Scenario D13R4. Mean phosphorus concentrations are summarized below:

Table 3

C-51 Basin	122 ppb
C-15 Basin	366 ppb
C-16 Basin	214 ppb
Hills. Basin	154 ppb
C-14 Basin	123 ppb
C-13 Basin	138 ppb
C-12 Basin	199 ppb
NNR Basin	43 ppb

The C-51, C-15, C-16, and Hillsboro basins contribute runoff to be stored in the Palm Beach Agricultural Reserve and Site 1 water storage areas/STAs. The combined flow-weighted mean concentration of phosphorus was calculated to be 166 ppb.

The C-14, C-13, C-12, and North New River basins contribute runoff to be stored in the North and Central Lake Belt water storage areas/STAs. The combined flow-weighted mean phosphorus concentration was calculated to be 80 ppb.

STA sizes necessary to treat runoff to an interim target phosphorus concentration of 50 ppb were calculated for the Site 1/WCA-2A and Lake Belt discharges using the above combined flow-weighted mean phosphorus concentrations. Calculations were performed by Siaka Kone, SFWMD. Using the settling rate constant of 10.2 m/yr from the conceptual design for the Everglades Construction Project, the following STA sizes were calculated:

Table 4

Site 1/Hillsboro STA	6,303 ac.
Lake Belt to ENP STA	1,238 ac.
Lake Belt to Biscayne Bay	1,083 ac

The sensitivity of STA size to enhanced STA performance (increased phosphorus settling rate constant) was also checked. Increasing the settling rate reduces the calculated area requirements for STAs.

Water quality data for contaminants other than phosphorus in Broward County surface waters (Hillsboro, C-14, C-13, C-11 basins) were also reviewed. Data summaries were provided by Dr. Nancy Gassman, Broward County DNRP. Mean dissolved oxygen levels were occasionally recorded below the State of Florida criterion (5.0 mg/l) and the Broward County criterion (4.0 mg/l). In addition to elevated concentrations of phosphorus, mean total nitrogen values occasionally exceeded the Broward County standard of 1.5 mg/l (there is no numeric criterion for total nitrogen in state water quality standards). Fecal coliform bacteria concentrations were also found to be occasionally elevated above the Florida and Broward County maximum concentration criterion (800-colonies/100 ml). Specific conductance at freshwater sites was also found to occasionally exceed the State of Florida Class III criterion (1275 u mhos/cm). Several trace metals have also been detected, including: arsenic, cadmium, chromium, copper, iron, lead, selenium, and zinc.

In sampling work conducted in 1997 and 1998, the following pesticides were also detected in Broward County surface waters: atrazine, diazanon, simazine, malathion, and ethion (BCDNRP 1999, draft).

Performance-Based Recommendations

None at this time; Scenario D13R4 was created to test the flexibility of the preferred alternative (Alternative D13R) to deliver increase flow volumes to Everglades National Park and Biscayne Bay. The Water Quality Subteam has identified a number of issues of concern (see Section IV below) which should be further addressed if the Restudy recommended plan was modified to perform as modeled in Scenario D13R4.

Subteam Issues

1. Restudy components must meet state and tribal water quality standards, as appropriate. In particular, increased flows to the Everglades Protection Area must meet the yet-to-be-established Phase 2 numeric phosphorus criterion (default concentration = 10 ppb). The technology best suited to achieve the Phase 2 phosphorus criterion has not yet been determined. Calculations performed to evaluate Scenario D13R4 indicate that the proposed treatment area size for the Site 1 STA (2,160 ac.) is not sufficient to meet interim phosphorus treatment requirements (to achieve 50 ppb, 6,303 ac. is required) for discharges to WCA-2A, let alone Phase 2 treatment requirements.

2. In addition to phosphorus, several other pollutants have been identified in the urban runoff to be captured, stored, treated, and discharged to WCA-2A, ENP, and Biscayne Bay. In some of the developed basins/sub-basins to be backpumped, there is minimal potential to retrofit those areas with standard stormwater BMPs (e.g., detention/retention, vegetative filters, etc.). Reduction of pollutant loads via stormwater BMPs may be problematic.

3. The treatment efficacy of STAs for some of the constituents of urban runoff are unknown, and surface water quality criteria have not been developed for some of the pollutants identified. The long-term cumulative effects and ecological risk of discharging treating urban runoff containing small concentrations of pollutants to natural systems must be evaluated fully as part of future planning and design efforts associated with Scenario D13R4 and subsequent alternatives that may involve the use of urban stormwater runoff as a source of water to the natural system.

4. Diverting urban runoff for storage and backpumping to the Everglades or redirecting runoff for discharge to Biscayne Bay may have a deleterious effect on existing downstream water bodies in Palm Beach and Broward Counties by reducing dilution effects. According to FDEP's 1998 Section 303(d) list of water bodies not meeting water quality standards, there are several water bodies in Palm Beach and Broward Counties not supporting designated uses (Class III waters). Diversion of runoff, especially relatively clean runoff, may result in degradation of water quality in downstream areas. Furthermore, backpumping of the C-13 and C-14 Canals may degrade water quality in western portions of the canals by bringing in water of lower water quality from the east. It should also be noted that the Broward County data reviewed are from quarterly sampling activities; stormwater runoff captured during and subsequent to storm events is likely to be of poorer quality containing first flush contaminants.

5. Scenario D13R4 creates a new point source discharge into the WCA-2A. This is not a desirable condition from a water quality perspective, as pollutants (and

ecological responses) are concentrated within the zone of influence of the point source discharge. If pursued, a spreader swale or other mechanism should be designed to create overland flow conditions.

6. Scenario D13R4 increases the volume of water discharged to WCA-3A via the modified S140 pump station (Component RR4; see Table 1). Although it is understood that the upstream sources of the S-140 flows involve ECP/Non-ECP facilities, if subsequent planning and design work indicates that the proposed scenario creates performance deficiencies in those facilities, modifications of those treatment facilities would be necessary to accommodate increased flows while meeting water quality standards for discharges to the Everglades Protection Area.

7. The operations description for Scenario D13R4 indicates that urban runoff stored in the deep impoundment area at Site 1 will be injected via ASR facilities proposed for that component (Component M). Water quality data reviewed to date show multiple violations of surface water quality criteria, including the presence of pesticides. Underground injection control (UIC) regulations require that drinking water standards must be met prior to injection into underground sources of drinking water. Considering the unknown efficacy of conventional STAs to treat all contaminants that may be present in urban runoff to drinking water standards, regulatory approval of ASR as proposed would be difficult under current UIC regulations.

8. Everglades National Park and Biscayne Bay are Outstanding Florida Waters (OFWs) pursuant to Florida Administrative Code rule 62-302. OFWs are subject to an anti-degradation requirement based on conditions at the time of OFW designation. Discharges of treated urban runoff containing minute concentrations of pollutants may conflict with OFW discharge regulatory criteria.

9. The settlement agreement to the federal Everglades lawsuit sets phosphorus concentration limits for Everglades National Park at Shark River Slough and Taylor Slough/Coastal Basins and defines a compliance determination methodology. Operations as proposed for Scenario D13R4 may necessitate modifications to the compliance determination methodology.

10. Scenario D13R4 creates a 343.0 k ac. ft./yr. (31-year average; see Table 1 in Section II, above) flow volume increase through the S-144-145-146 structures complex, which discharge flows from WCA-2A to 2B. The long-term cumulative effects and ecological response of a flow increase of this magnitude must be evaluated fully as part of future planning and design efforts associated with Scenario D13R4. Also, it should be noted that the S-144-145-146 structures are governed by the Non-ECP discharge structures requirements of the EFA; schedules and strategies developed under the EFA to assure that water quality standards in the EPA are met may have to be modified to account for increased flows in this location.

General Recommendations

1. If Scenario D13R4 D13R4 or other alternatives that involve the use of urban stormwater runoff as a source of water for the natural system are to be pursued further, conceptual treatment area sizes should be increased to provide adequate treatment capacity per standard design practices. Additional contingencies (land area requirements, construction and operation costs) should be included in future planning and design actions to assure that EFA Phase 2 treatment requirements will be met for discharges to WCA-2A and Everglades National Park.

2. Alternative routing and treatment facilities to deliver increased overland flows to Everglades National Park and surface water flows to Biscayne Bay should be consider.

3. The Everglades Water Quality and Everglades Landscape Models should be run to compare water quality and ecological responses of Scenario D13R4 to Future Base and Alternative D13R simulated conditions (and other alternatives which involve the use of urban stormwater runoff as a source of water for the natural system) to Future Base and Alternative D13R simulated conditions. A subsequent evaluation should then be conducted by the Water Quality Team.

4. Local monitoring programs should be utilized to provide additional information for refining treatment technologies and the sizes of treatment areas necessary to reduce concentrations of pollutants in future detailed planning and design work.

5. Water and habitat quality impacts to natural areas east of the WCAs should also be investigated for those basins acting as sources of runoff.

Seminole Tribe of Florida comments on Water Quality

The Seminole Tribe of Florida commented on the need for a RASTA in the C-41 Basin in D13R4. The Seminole Tribe's Brighton Reservation is located in this Basin.

The Seminole Tribe of Florida recognizes the need to improve Lake Okeechobee water quality; however, the Tribe does not support the use of Tribal lands to clean pollution caused by others.

Total Systems

Fragmentation Performance Measure

In D13R4, the number of miles of canals and levees stayed the same as in D13R. This performance measure is based on the artificial structures within the Everglades Protection Area, Rotenberger and Holey Land Wildlife Management

Areas, Big Cypress National Preserve because these structures affect natural resources more so than those found within the urban or agricultural area. Any additional structures constructed as part of D13R4 would be located outside the natural system so they were not included in this measure.

Table 5. Miles of Canals and Levees.

	1995 Base	2050 Base	D13R	D13R4	1995 Base – D13R4
Miles of Canals	330	311	184	184	-146
Miles of Levees	400	400	318	318	-82

Continuity Performance Measure

Hydropattern Comparison Across Barriers: The overall score for Alternative D13R for the differences in water levels across barriers or transects was 0.6 for all eight transects including Loxahatchee NWR (WCA-1) and the remaining barrier between WCA-2 and WCA-3. Alternative D13R4's score was also 0.6. The score remains relatively low because the system is not completely decompartmentalized.

Table 6. Continuity: Water level differences across barriers compared to NSM.

	1995 Base	2050 Base	D13R	D13R4
LNWR/WCA2	0.0	0.0	0.0	0.0
WCA2-3	0.0	0.0	0.0	0.0
Miami Canal North	0.1	0.4	0.5	0.5
Miami Canal South	1.0	1.0	1.0	1.0
L-67	0.0	0.1	0.2	0.2
Tamiami Trail West	0.0	0.4	1.0	1.0
Tamiami Trail East	0.5	0.7	1.0	1.0
L-28	0.6	0.9	1.0	1.0
Average 3-9	**0.4**	**0.6**	**0.8**	**0.8**
Average 1-8	**0.3**	**0.4**	**0.6**	**0.6**

Sheetflow Performance Measure

Average annual overland flow volumes across a variety of transects showed both improvements and reductions in flow between D13R and D13R4 but the final overall score improved from 0.7 to 0.8, if L-67 was included; both scores were 0.9 if L-67 was excluded. Improvements were seen in dry season flows across T-8, the transect across eastern Alligator Alley, and both wet and dry season flows westward across T-21 Shark River Slough and T-18, eastern Tamiami Trail. Dry season flows were reduced across T-25 in the eastern Big Cypress and T-7 in Alligator Alley west. The biggest differences were seen across two transects not used in earlier analyses because no changes had been seen before. Flows across T-19, the north-south transect just west of L-31N and T-20, the L-67 extension, reversed direction to their normal westward flow and volumes increased greatly. Between D13R and D13R4, scores for T-19, west of L-31N improved from (dry season) 0.6 to 0.9 and (wet season) 0.5 to 1.0. T-20 (L-67 extension) scores rose from (dry season) 0.7 to 0.8 and (wet season) 0.7 to 0.9.

Table 7. Flow volumes across transects.

	1995 Base	2050 Base	D13R	D13R4
Big Cypress Group	0.8	0.3	0.9	0.9
Central Everglades	0.8	0.3	0.8	0.8
Southern Everglades	0.8	0.3	0.9	1.0
Tamiami Trail Group	0.6	0.2	0.9	0.9
L-67	0.1	0.0	0.1	0.1
Score (avg. of all)	**0.6**	**0.2**	**0.7**	**0.8**
Score (w/o L-67)	**0.6**	**0.3**	**0.9**	**0.9**
East ENP (new)			0.6	0.9

LAKE OKEECHOBEE

1995 Base

Under the revised 1995 Base, hydrologic conditions are not optimal for the lake ecosystem, in terms of the frequency of extreme high and low lake stage events.

The lake experiences 3 events per decade (on average) in which stages fall below 11 ft, a low water depth at which nearly all of the littoral zone is dry and unsuitable as habitat for fish and other aquatic biota. This equates to a score of 0.4, reflecting poor conditions from the standpoint of protecting ecosystem health. Prolonged moderate low lake stages (<12 ft for > 1 year) occur at a frequency of 1 in 10 years, giving a score of 0.9, indicating good conditions for ecosystem health. Extreme high lake stages (>17 ft), which can cause wind and wave damage to near-shore plant communities and transport nutrients into the pristine littoral zone, occur at a frequency of 2 in 10 years, giving a score of 0.7, indicating moderate conditions. Prolonged moderate high lake stages (>15 ft for > 1 year), which harm the ecosystem through a variety of mechanisms (reduced light penetration, loss of benthic plants, increased circulation of nutrient rich water to near-littoral regions) occur at a frequency of 2 in 10 years. This gives a score of 0.7, again indicating moderate conditions. Spring (January – May) lake level recessions (from 15 to 12 ft), considered beneficial to various ecosystem components, occur only twice per decade (on average). This is considered to be too infrequent to support a healthy littoral zone. The performance measure receives a score of 0.

Overall, the 1995 base condition receives a score of 0.6, indicating conditions that are not suitable for long-term support of a healthy lake ecosystem.

2050 Base

Conditions worsen for Lake Okeechobee under the 2050 Base, in regard to an increased frequency of harmful low water events caused by greater regional demands on the lake. However, there are fewer harmful high water events under this base condition than under the 1995 Base.

The lake experiences 4 events per decade (on average) in which stages fall below 11 ft. This equates to a score of 0, reflecting a high likelihood of severe harm to the ecosystem and its values. Prolonged moderate low lake stages (<12 ft for > 1 year) occur at a 2 in 10 year frequency, giving a score of 0.7, reflecting moderate conditions. Extreme high lake stages (>17 ft) and prolonged moderate high lake stages (>15 ft for >1 year) occur at frequencies of 1 in 10 and 2 in 10 years, respectively, giving scores of 0.9 (good) and 0.7 (moderate). As in the 1995 base, spring lake level recessions occur only once every five years, and the associated performance measure receives a score of 0, reflecting harmful conditions for the littoral zone.

Overall, the 2050 base condition receives a score of 0.5, indicating conditions that are detrimental to the long-term health of the lake ecosystem.

Alternatives D13R, D13R2 and D13R4

The hydrologic conditions experienced by Lake Okeechobee are nearly identical (from the standpoint of ecological effects) for planning alternatives D13R, D13R2 and D13R4. All three represent substantial improvements in comparison with the 1995 and 2050 base conditions. Over 70% of the stage duration curve falls within the restoration goal of a 12 to 15 ft depth range under these alternative plans, as compared with only 50% under the 1995 Base and 45% under the 2050 Base.

Under alternatives D13R, D13R2 and D13R4, extreme low lake stage events (<11 ft) occur at a frequency of 1 in 10 years (on average), giving a score of 0.9 (good). Prolonged moderate low lake stages (<12 ft for >1 year) occur less often than 1 in 10 years, giving a score of 1.0 (excellent). Prolonged moderate high lake stages (>15 ft for >1 year) and extreme high lake stages (>17 ft) occur at frequencies of 1 in 10 years. This gives scores of 0.9 (good) for these performance measures. There are, on average, 3 spring recession events per decade under these alternatives, and this equates to a score of 0.

The overall score for alternatives D13R, D13R2 and D13R4 are 0.8, indicating moderate to good conditions.

Conclusions

The 2050 Base, with increased regional demands on the lake, and without features of the Restudy, has two effects on Lake Okeechobee: (1) it worsens conditions in regard to more frequent low stage events; and (2) it improves conditions in terms of fewer extreme high stage events. This does not represent a balanced improvement for the ecosystem, which is what the Restudy is striving to achieve.

Alternatives D13R, D13R2 and D13R4, which are nearly identical in performance, represent marked improvements in hydrologic conditions for the lake. Hydrologic conditions in the lake not only are improved over the 2050 Base, but also are improved relative to the 1995 Base; this means that alternatives D13R, D13R2 and D13R4 may be viewed as progress towards restoration.

At this point, it should be reiterated that the improved scores under the D13R alternatives are clearly a function of extensive use of ASR to move water out of and into the lake during periods of high and low lake stages, respectively.. If this technology proves to be infeasible, hydrologic benefits to the lake observed in the alternatives may be substantially reduced. A previous scenario involving removal of Lake Okeechobee ASR resulted in substantially inferior performance, both in terms of extreme high and low lake stage events.

Table 8. Scores for the priority hydrologic performance measures for Lake Okeechobee.

Performance Measure	1995 Base		2050 Base		Alt D13R		Alt D13R2		Alt D13R4	
	#	score	#	score	#	score	#	score	#	score
<11 ft	3	0.4	4	0.0	1	0.9	1	0.9	1	0.9
<12 ft / >1 yr	1	0.9	2	0.7	0	1.0	0	1.0	0	1.0
>15 ft / >1 yr	2	0.7	1	0.9	1	0.9	1	0.9	1	0.9
>17 ft	2	0.7	2	0.7	1	0.9	1	0.9	1	0.9
Sp. Recession	2	0.0	2	0.0	3	0.0	3	0.0	3	0.0
Weighted CSI		**0.6**		**0.5**		**0.8**		**0.8**		**0.8**

values indicate the number of events per decade (average for 30-yr period of record); scores are calculated as described in the document entitled "Priority Hydrologic Performance Measures for Lake Okeechobee," and the weighted CSI value is calculated using the Lake Okeechobee ROGEM equation.

Lake Okeechobee Service Area

This section presents the Lake Okeechobee Service Area (LOSA) sub-team evaluation and scoring results for Restudy Alternative D13R4.

First, results of earlier evaluations are summarized to set a context for the evaluation of D13R4. The LOSA sub-team in its previous reports indicated that Alternatives A, C and D come close to meeting the water supply level of service goal and are judged to have good performance, with Alternative D being clearly the best performer. When the LOSA sub-team evaluated Alternative D13R, it found that the modifications to Alternative D13 that resulted in Alternative D13R had no significant effect on the good performance of Alternative D with respect to Lake Okeechobee Service Area water supply.

The principal goal utilized by the LOSA sub-team was that the alternatives should be able to meet all demands in a 1 in 10-year drought. It was also agreed that the best available indicator that this was being done would be if the number of years with water shortage restrictions were not more than 3 in the simulation period. In developing the count of years with water restrictions, certain events with very minor restrictions were not counted. None of the alternatives reach this goal (3 or less events) but with 5 events Alternatives D, D13R and D13R4 all come close.

The strong performance of Alternatives A, C and D is further evidenced when the duration (total months of supply side management with restrictions greater than 18,000 acre feet/year) of the water restriction periods is considered. For Alternative D, LOSA is under restrictions only 9 months in the simulation period, while for Alternatives D13R and D13R4 there are only 8 months of restrictions.

The same scoring analysis, which was completed for earlier alternatives, was also completed for Alternative D13R4. The reader is referred to the previous evaluations for explanations of the rationale and procedure for the scoring analysis. The scoring results for Alternatives D, D13R and D13R4 are provided in Table 9 below. Attachments A and B detail the calculations presented in Table 9. The data in the table indicate that all three alternatives score essentially the same. Alternatives D13R and D13R4 show a slightly better score because they each have one less month of water shortage than does Alternative D.

Table 9 – LOSA Water Supply Scoring Results for Alternatives D, D13R and D13R4.

Alternative	Frequency Score	Duration/ Severity Score	Combined Score
Alternative D	0.926	0.853	0.890
Alternative D13R	0.926	0.862	0.894
Alternative D13R4	0.926	0.862	0.894

Attachment A
Calculation of Frequency Scores

Alternative	Number of Water Years with Restrictions	Frequency Score = (30 – Years with Restrictions)/27
Alternative D	5	0.926
Alternative D13R	5	0.926
Alternative D13R4	5	0.926

Attachment B
Calculation of Duration/Severity Scores

Note that the scaled duration/severity score is calculated using the following formula:

Scaled duration/severity score = 1 – (Combined Duration Severity Score for the Alternative÷Combined Duration Severity Score for the Worst Alternative)

= 1 – (Combined Duration Severity Score for the Alternative÷109).

Alternative D

Water Years With SSM Cutbacks	Highest Monthly Cutback	Severity Score	Duration Score	Combined Duration/ Severity Score = Severity Score + Duration Score
1981	168,350	4	4	8
1982	95,040	2	3	5
1990	39,820	1	2	3
Total Combined Duration/Severity Score				16
Scaled Duration/Severity Score				.853

Alternative D13R

Water Years With	Highest	Severity	Duration	Combined

SSM Cutbacks	Monthly Cutback	Score	Score	Duration/ Severity Score = Severity Score + Duration Score
1981	167,720	4	4	8
1982	95,140	2	3	5
1990	39,680	1	1	2
Total Combined Duration/Severity Score				15
Scaled Duration/Severity Score				.862

Alternative D13R4

Water Years With SSM Cutbacks	Highest Monthly Cutback	Severity Score	Duration Score	Combined Duration/ Severity Score = Severity Score + Duration Score
1981	166,570	4	4	8
1982	98,050	2	3	5
1990	36,350	1	1	2
Total Combined Duration/Severity Score				15
Scaled Duration/Severity Score				.862

Caloosahatchee Estuary

Performance Measure: The number of times salinity envelope criteria were not met for the Caloosahatchee Estuary.
Goal: A base flow of 300 cfs is needed to maintain appropriate salinities.
Performance: The number of minimum flow violations is well below the target value and the same as D13R.

Performance Measure: The number of times high discharge criteria (mean monthly flow > 2,800 and 4,500 cfs) were exceeded for the Caloosahatchee Estuary.
Performance: The number of high flow violations is well below the target value and the same as D13R.

Performance Measure: Regulatory releases from Lake Okeechobee.
Goal: None are desired.
Note: D13R4 had one regulatory release.

Recommendations: Overall, D13R4 is the same as D13R in the Caloosahatchee basin.

St. Lucie Estuary

Performance Measure: Number of times salinity envelope criteria were not met for the St. Lucie Estuary.
Goal: A base flow of 350 cfs is needed to maintain appropriate salinities.
Performance: D13R4 is the same as D13R and the base flow target has been met.

Performance Measure: Number of times high discharge criteria (mean monthly flow > 1,600 & 2,500 cfs) were exceeded for the St. Lucie Estuary.
Goal: No regulatory releases, and reduction in high discharges for > 14 days.

D13R4 is the same as D13R, except that D13R4 has one more >1600 cfs violation. In both D13R and D13R4, the targets are almost met for that estuary (See the St. Lucie issue paper for the AET).

Recommendations: Detailed planning in the Indian River Lagoon Feasibility Study should be able to help make any additional improvements.

Lake Worth Lagoon

Performance Measure: Wet/Dry Season Average Flows Discharged to Lake Worth through S-40, S-41 & S-155 for the 31-year simulation.
Goal: To meet target flows to the Lake Worth Lagoon (0 - 500 cfs).
Performance: D13R4 is greatly improved over D13R and is the best plan so far. Much of the flow to the Lake Worth Lagoon was captured and sent south. The number of times the flow is >500 cfs decreased from 96 to 22 events in D13R4.

Northern and Central Everglades

Loxahatchee NWR (Indicator Regions 26 and 27)

Average annual hydroperiods in both indicator regions 26 and 27 are within 1% of target values defined by the 1995 Base and closely match Alternative D13R results. Compared to Alternative D13R, the mean inundation duration in Alternative D13R4 decreases slightly in north LNWR according to the performance of Indicator Region 27 (96 weeks in Alternative D13R compared to 85 weeks in Alternative D13R4) but the number of events increases (16 events in D13R, 18 events in D13R4). Inundation duration and number of events in indicator region 26 (south LNWR) exactly match Alternative D13R results.

Average annual duration of extreme low water events remains at 0% for both indicator regions meeting 1995 Base target values.

Extreme high water performance in Alternative D13R4 closely matches Alternative D13R. As stated in previous alternative evaluation summaries for this region, there remains uncertainty about the effect of high water on tree islands in southern LNWR. However, alternative D13R4 conforms overall to current hydrologic management objectives for the refuge.

Holey Land and Rotenberger WMAs

This region performs identically to Alternative D13R.

WCA-2A

Southern WCA-2A developed a problem with extreme high water under the D13R4 scenario. In Indicator Region 24 there are 52 weeks of depths greater than 2.5 ft over the 31 year period of record, compared with 18 weeks under D13R, 9 under the 2050 Base, 3 under the 1995 Base, and zero under NSM.

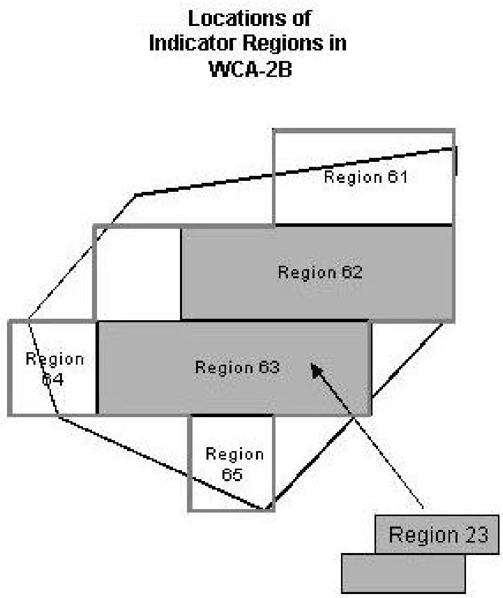
Southern WCA-2A had an excess of dry-downs to more than 1.0 ft below ground in D13R (12 events occupying 5% of time). It was hoped that discharges into WCA-2A from the Site 1 facility would alleviate this problem in D13R4. Unfortunately, flows from Site 1 are largely during the wet season and lead to increased high water, without alleviating the low water problem.

WCA-2B

The frequencies of extreme high and low water in Indicator Region 23 are very similar in D13R4 and D13R. However, when Indicator Region 23 is split into two separate indicator regions, improvements are seen by way of a lower frequency of extreme low water in the northern portions of the WCA. “New” Indicator Region 62 (Fig 1), which consists of the northern three cells of Indicator Region 23, shows a reduction in the frequency of depths more than 1.0 ft below ground, from 13% in D13R to 9% of time in D13R4. Although there is a slight increase in the frequency of extreme high water compared to D13 (5% vs. 3%), this is accompanied by a substantial improvement in hydroperiod, from 59% in D13R to 79% in D13R4. Overall, Indicator Region 62 has reduced low water compared to the 1995 Base and reduced high water compared to the 2050 Base. This area may be approaching conditions that are “NSM-like” for a sawgrass plains type of landscape, but the frequency of extreme low water is still of concern.

“New” Indicator Region 63, which occupies the southern and less-elevated part of Indicator Region 23 (Fig 1), exhibits a lower frequency of depths greater than 2.5 ft compared to D13R (27% vs. 33% of time). Both D13R and D13R4 are substantial improvements over the 1995 and 2050 Bases for extreme high water but they remain outside the range of NSM values for high water frequencies in the remnant peat landscape.

Figure 1



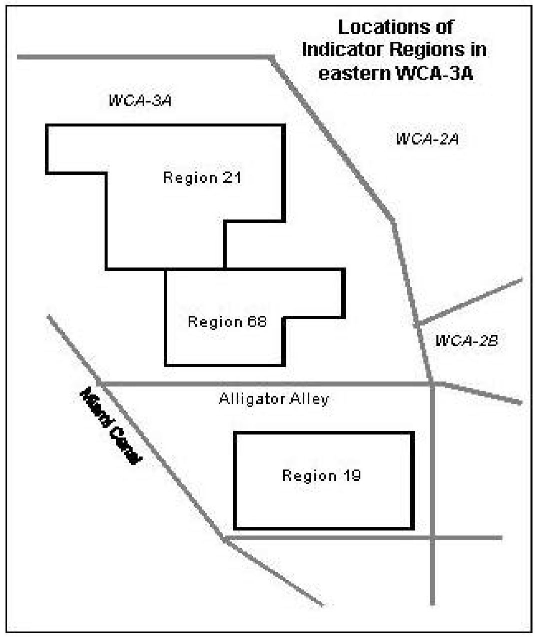
Eastern and Northeastern WCA-3A

The overall frequency of extreme high water in eastern and northeastern WCA-3A is reduced relative to D13R. In NE WCA-3A (Indicator Region 21), extreme high water is one-third as frequent in D13R4 as in D13R (2 vs. 6 events, occupying 1% rather than 3% of time); D13R4 is about the same as the 1995 and 2050 Bases (marginally better), whereas D13R had more frequent extreme high water than either Base. In Eastern WCA-3A (Indicator Region19), the frequency of depths greater than 2.5 ft is reduced from 19% of time in D13R to 15% of time in D13R4; both models had less extreme high water than the 1995 Base but more than the 2050 Base. In between these two indicator regions, in “new” Indicator Region 68 (Fig 2), trends are similar to those seen in Indicator Region19 although there is a much lower absolute frequency of extreme high water. When compared with NSM, Indicator Region 21 is similar to target values, but Indicator Regions 19 and 68 are not.

Extreme low water in northeastern WCA-3A (Indicator Region 21) is not improved in D13R4 compared to D13R, but is still slightly worse than the 2050 Base conditions.

Overall, performance is improved within WCA-3A east of the Miami Canal, but the area south of Alligator Alley still remains far from NSM target values for extreme high water.

Figure 2



WCA-3B

The frequency of extreme high water in WCA-3B increased in D13R4 compared to D13R, for all four indicator regions evaluated. Indicator Region 15 in western WCA-3B increased from five high water events under D13R (3% of time) to 10 high water events under D13R4 (5% of time); this is more extreme than the 1995 Base (1% high water) and similar to the 2050 Base (5% high water). Indicator Region 16 in eastern WCA-3B has an increase from 13 high water events in D13R (5% of time) to 19 high water events in D13R4 (11% of time). This is more extreme than either the 1995 or 2050 bases (3% and 8% high water, respectively). It is also a high frequency of extreme depths than that seen under NSM for any indicator regions within the remnant peat landscape. Two “new” indicator regions that were delineated in northern WCA-3B (Indicator Regions 22 and 27) also show increases in the frequency of extreme high water in D13R4 compared with D13R.

Pennsuco Wetlands

Both water levels and hydroperiods worsened relative to D13R. D13R4 resulted in a substantial increase in the number of high water events over those reported for both bases and D13R. In addition, the average duration of flooding in

Pennsuco North has more than doubled relative to NSM projections and is more than 4 times longer than either base condition. Water levels in the Pennsuco increased relative to D13R and were sufficiently higher in D13R4 to present a threat to tree island resources in the basin.

*Pennsuco North Stage Duration Curve: The D13R4 curve is higher than the 1995 and 2050 Bases and higher than D13R. The D13R4 curve shows slightly higher water levels than D13R during most of the period of record, but water levels are reduced relative to D13R2. The high water level exceedance count shows a strong increase in the number of weeks where the high water target is exceeded for D13R2 (147 weeks) and D13R4 (196 weeks) relative to D13R (23 weeks). The stage hydrographs show that several of these high water events are of sufficient duration to cause possible flooding impacts to existing tree islands. Inundation pattern shows that there would be no drydown for most years in this basin if D13R4 were implemented as described. D13R hydroperiod and hydropattern would be preferred for this region.

*Pennsuco South Stage Duration Curve: Same comments as Pennsuco North, but the number of weeks that the high water target is exceeded is 118 weeks for D13R2, 161 weeks for D13R4, and 18 weeks for D13R.

Overall Northern and Central Everglades

There is some improvement in two areas – eastern/northeastern WCA-3A and WCA-2B – that were deficient under D13R; however, these areas still deviate from target conditions. Other areas, notably southern WCA-2A and WCA-3B, deviate further from targets than under D13R. Overall, substantial regions of the WCA system fall outside the range of performance seen in NSM for indicator regions in the peat landscape. D13R4 performance in southern and south central WCA-3A was relatively similar to D13R.

Southern Everglades

Alternative D13R provides substantial improvement toward the attainment of restoration targets for the southern Everglades in comparison to base conditions and Alternative D. However, questions remain about D13R regarding its adequacy in achieving restoration in three areas of the southern Everglades. Those areas are annual flow volumes down Shark River Slough, related salinity regimes in the coastal basins of Florida Bay, and duration of uninterrupted flooding in the rockland marl marsh. The additional hydrologic modeling that led to D13R4 determines how much performance in the three areas can be improved by capturing runoff that is presently lost to tide along the lower east coast. The modeling exercise captures runoff that does not appear necessary to prevent saltwater intrusion or to sustain the water demands of the lower east coast service areas. It routes that water either through the water conservation areas or through the eastern flow corridor for delivery either to northeast Shark River Slough or to Biscayne Bay.

Two major concerns that surface during the D13R4 modeling exercise are water quality and water conservation area hydrologic parameters. For the first time in alternative plan analyses for the Restudy, urban runoff water is delivered to the natural system. While provisions are made in the modeling to treat the questionable water quality of that urban runoff, uncertainty is acknowledged regarding both the adequacy of that treatment and the level of treatment that will be necessary before the delivery of such water to the natural system. The other concern is that efforts to correct the problems in the southern Everglades exacerbate ecologically damaging high water conditions in portions of the water conservation areas. Both of these problems must be addressed in detailed design before the features modeled in D13R4 can be implemented.

The following analysis focuses on the benefits of D13R4 regarding the three problem areas in the southern Everglades. The many other performance measures that have been analyzed in previous model runs are more cursorily examined to insure that D13R4 has not decreased performance in those areas.

Shark River Slough

D13R4 provides a mean annual flow volume of 1,258 acre feet down mid Shark River Slough, which represents a 166,000 acre foot annual average increase compared to D13R. The performance of D13R4 translates to 81% achievement of the NSN45F target of 1,561,100-acre feet/year, compared to 70% under D13R, 52% under 2050BSR, and 44% under 1995BSR.

The increased flow volume down Shark River Slough has no net effect on the number of dry events during the period of record in the slough indicator regions, compared to D13R, because most of the increased flow volume occurs during the wet season. Likewise, there is only slight improvement in the seasonal distribution of flows in an increase from 92% concordance with NSM45F in D13R to 94% in D13R4. Mean depth during periods of flooding shows a modest increase from a 77% match in D13R to an 83% match in D13R4.

Florida Bay Coastal Basins

The gains in Shark River Slough flow volume and water depth are reflected in water stages at the P-33 gage in the central slough. The stage at P-33 is correlated to salinity in the coastal basins of Florida Bay, in that P33 stage is indicative of freshwater heads throughout much of Everglades National Park that drive flow to the coastal basins. Stages equaling or exceeding 6.3 feet msl at P-33 indicate the avoidance of undesirable high-salinity events in the coastal basins. Stages of 6.3+ increase in frequency from 220 months in D13R to 235 months in D13R4 during the 31-year period of record. This represents a 91% achievement of the NSM45F target of 258 months, compared to 85% in D13R, 69% in 50BSR, and

48% in 95BSR. Stages equaling or exceeding 7.3 feet msl, indicate the attainment of desirable low-salinity events in the coastal basins. Stages of 7.3+ increase in frequency from 16 months in D13R to 23 months in D13R4 during the 31-year period of record. This represents a 77% achievement of the NSM45F target of 30 months compared to 53% in D13R, 7% in 2050BSR, and 23% in 1995BSR.

Rockland Marl Marsh

The gains in Shark River Slough flow volume also extend to the higher-elevation wetlands of the Rockland Marl Marsh to the east of the slough. The mean duration of uninterrupted flooding in the Rockland Marl Marsh increases from 30 weeks in D13R to 37 weeks in D13R4. The performance of D13R4 represents an84% achievement of the 44-week NSM45F target, compared to 68% in D13R, 52% in 2050BSR, and 27% in 1995BSR. Accompanying the increase in mean duration of flooding is a decrease in the mean duration of dry events from 21 weeks in D13R to 18 weeks in D13R4.

Conclusions for Southern Everglades

The hydrologic benefits to the southern Everglades of Alternative D13R can be increased if the features of model run D13R4 can be incorporated during the detailed modeling and design phases of the Restudy. Performance increased to greater than 80% of the NSM45F target in each of the three problem areas that were identified for the southern Everglades – Shark River Slough flow volume, Florida Bay coastal basin salinity regime, and Rockland Marl Marsh duration of uninterrupted flooding. The endorsement of the benefits of D13R4 in the southern Everglades is strongly conditional on addressing the water quality concerns and correcting the high-water conditions in the Water Conservation Areas during detailed modeling and design.

Lower East Coast Service Area

Procedure and Scores of Alternatives and Base Conditions

Location

The Lower East Coast Service Area (LECSA) is divided into four service areas: North Palm Beach, and Service Areas 1, 2, and 3. The North Palm Beach Service Area extends from northern to central Palm Beach County, encompassing approximately one-third of the county and includes one primary canal, the C-17. Service Area 1 covers the remainder of Palm Beach County and a small portion of Broward County to just below the Hillsboro Canal. There are four primary canals that traverse the service area: C-51, C-16, C-12, and the Hillsboro Canal. Service Area 2 includes most of Broward County and a portion of Miami-Dade County. It extends south from the Hillsboro Basin to just south of the C-9, which lies in Miami-Dade County. Four primary coastal canals extend through Service Area 2: C-14, C-

13, North New River, and C-9. Service Area 3 includes the remainder of Miami-Dade County from the C-9 Basin south to near the tip of the peninsula. There are three primary coastal canals in Service Area 3: C-4, C-6 and C-2. Although the county boundaries extend west to the center of the state, the service areas only include those portions of the counties east of the protective levees.

Background: Water Supply

The performance measures used for the Lower East Coast to evaluate Restudy alternatives for water supply relate to the frequency and duration of water supply cutback events and the ability to maintain primary coastal canals. Water supply cutbacks are mandatory reductions imposed by the District on the LECSA utilities and general population to conserve existing water supplies when a shortage is imminent. Water supply cutback events usually occur during the dry season, when replenishment of stored water is limited.

During the dry season structural releases are periodically made from the Water Conservation Areas (WCAs) and Lake Okeechobee to maintain ground water levels and to minimize the possibility of saltwater intrusion along the coast. The Lower East Coast uses this water from the regional system to recharge secondary canal networks, wellfields and other recharge areas, and lakes. These ancillary systems are maintained by the local utilities to continue meeting public water supply demands. During the wet season and under normal conditions, rainfall and seepage account for the vast majority of recharge to the LECSA surface and ground water system that supplies this area.

During extended dry periods, Lake Okeechobee and the WCAs are important sources of surface water supply for large regions of South Florida. WCAs 1, 2A and 3A are the primary sources of supplemental surface water supply for the Lower East Coast Service Areas 1, 2, and 3, respectively. When water stored in the WCAs and Lake Okeechobee is scarce, for instance during a drought, the urban water supply demands are restricted (cut back) in order to conserve the remaining supplies in the regional system. Although the service areas are able to continue to meet some demands through local sources, all service areas are dependent on the WCAs and Lake Okeechobee to supplement surface water supply and support urban public water supply demands. This is true for all of the service areas except Northern Palm Beach Service Area, which relies on local supplies.

The availability of recharge water to the LECSA via surface or ground water through either seepage or structural flows from the regional system can be evaluated based on the surface water storage in Lake Okeechobee. The storage volume within the lake gives a more quantitative indicator that a water shortage condition may be approaching. The water supply cutbacks in the LECSA are based partly on the available surface water storage in Lake Okeechobee. However, the primary triggering mechanism for implementing the LECSA cutbacks is related to ground water levels within the LECSA.

Low ground water levels near the coast increase the vulnerability of the Biscayne aquifer to saltwater intrusion. Continuing to meet urban water demands may exacerbate ground water levels and therefore cutbacks are necessary when there is a threat to the resource. Low storage levels in the Lake Okeechobee at the beginning of the dry season are indicative of a prolonged storage problem that dictates when the cutbacks can be removed while low ground water levels indicate immediate problems within the LECSA. Either of these triggers, Lake Okeechobee or local ground water levels, can initiate a water supply cutback and are reflected in the ability to meet the 1-in-10 level of service water supply goal. Although regional water supplies or local ground water levels may rebound during the dry season, cutbacks are continued through the end of the dry season, May, to ensure protection of the Biscayne aquifer.

The availability of water from the regional system to recharge the LECSA via structural discharges can be evaluated based on the ability to maintain the primary coastal canals above their saltwater intrusion criteria. This third performance measure, maintaining the surface water levels and continuing their recharge functions, is critical to protecting the Biscayne aquifer from saltwater intrusion. However, it should be noted that saltwater intrusion could still occur even if the primary canals are maintained. Some areas along the salt front cannot be adequately recharged from the regional system to offset local demands on ground and surface waters or to abate saltwater intrusion. Local conditions and demands can contribute to the movement of the salt front as well by lowering ground water levels.

The primary coastal canal performance measure is indicative of the ability to meet the proposed criteria for minimum flows and levels for the Biscayne aquifer. Chapter 373, F.S. directs all of the water management districts to establish minimum flows and levels for surface waters and aquifers within their jurisdiction. The District will be proceeding with rule development for the minimum level criteria for the Biscayne aquifer in the near future. The minimum level criteria for the Biscayne aquifer was utilized in the SFWMM model to reflect future demands from the regional system.

The performance measures described herein rely upon a linear relationship between performance and the scores developed for comparative purposes. Only the 1-in-10 level of service performance measure was normalized. No weighting was applied to the performance measures since all were considered equally important to continue the functions of the Biscayne aquifer and other resources in the Lower East Coast.

Performance Measures and Indicators

Two performance measures and one performance indicator are analyzed for each service area. In Service Area 3, an additional performance indicator, Ability to maintain South Miami-Dade Canals, was analyzed. These performance measures were selected due to their ability to measure how the alternative performs in protecting the Biscayne aquifer and providing recharge to the aquifer for public water supply. These measures are indicative of how well the conceptual designs may perform together on a regional scale. Additional feasibility studies and detailed designs will need to be pursued prior to implementation of any of the components included in the Comprehensive Plan.

1) **Ability to meet the 1-in-10 water supply planning goal:** The frequency of water supply cutbacks is indicative of the reliability of regional and local water supplies through various weather and resource conditions. Water supplies in Lake Okeechobee supplement deliveries to the LECSA to maintain ground water levels to prevent saltwater intrusion near the coast. Public water supplies are reduced or cutback at the well field in response to low surface water levels in Lake Okeechobee or ground water levels near the coast. The planning goal is to find a balance between ability of the regional system to supplement recharge of the aquifer and meet the public water supply planning goal of a 1-in-10 year level of service in the lower east coast of Florida. The planning goal is in terms of the frequency of cutback events and is defined as no more than three cutback events, no more than seven months in duration over the period of record. A cutback event can begin in the fall and continue through the spring, therefore the maximum number of cutback events in the period of record is thirty. The score represents the number of cutback events during the period of record minus the three allowed events compared to the maximum number of years the 1-in-10 year level of service planning goal can be met. Alternatives that equaled or exceeded the goal, i.e. had three or less cutback events, scored 100% (no extra credit was given for exceeding the planning goal).

Score =[1   ((# of cutback events   3 years)/27 years)]100 = % of years goal met

2) **Percentage of months not in a water supply cutback:** The duration of water supply cutbacks is another characteristic of a drought event and is used as an indicator of the reliability of water supplies. The number of months of water supply cutbacks incurred in a service area capture the lengths of time urban demands are not met. The increased or decreased length of the cutback events is captured by counting the total number of months when the service area is in a water supply cutback, regardless of the severity of the cutback, as a percentage of the total number of months in the period of record. This percentage of time would be subtracted from one to reflect the improvement, increasing amount of time not in a water supply cutback, attributable to the alternative.

Score =[1 ((# of months service area in cutback)/372 months)]100 = % of time in a cutback

3) **Ability to maintain saltwater intrusion criteria:** Maintaining the primary coastal canals above the saltwater intrusion criteria is critical to protecting the Biscayne aquifer from saltwater intrusion and is part of the proposed criteria for minimum flows and levels. Each Service Area includes several primary coastal canals that have saltwater intrusion criteria developed for them. In the SFWMM, the stage of the coastal canal is compared to the criteria on a daily basis. If the canal is unable to be maintained for a week, the event is counted towards the time the saltwater intrusion criteria was not met. All canals were weighted equally except in Service Area 3, where the C-6 and C-2 were weighted more than the C-4 due to their ability to provide wellfield recharge. The performance measure is reported as the percentage of time the canal stage is below the saltwater intrusion criterion, which is subtracted from one to report the percentage of time the canal is above the saltwater intrusion criterion.

Score = [1- % of time not able to maintain canals]100 = % of time able to maintain canals

4) **Maintaining water levels in south Miami-Dade canals:** At this time, saltwater intrusion criteria do not exist for the major canals in southern Miami-Dade County. However, it is important to evaluate water levels in these canals because encroachment of the salt front into the Biscayne aquifer has occurred previously in this area. Plus, major public water supply wellfields are located in southern Miami-Dade County. This area was evaluated by using the stage duration curves for the following structures: C-100A @ S-123, C-1 @ S-21, C-102 @ S-21A, and C-103 @ S-20F. The stage duration curves were used to evaluate the alternatives in two ways: 1) the distance by which an alternative's water level fails to reach two feet NGVD at the 90th percentile of the stage duration curve; and 2) the percentile at which an alternative's stage duration curve meets the 50th percentile of the 1995 Base stage duration curve.

In the first scenario, two feet NGVD was used for comparison in keeping with the Ghyben-Herzberg relationship which estimates that one foot of fresh water head is required to protect 40 feet of aquifer. The aquifer along the coast in southern Miami-Dade is approximately 80 feet that would require two feet of fresh water head. The 90th percentile of the stage duration curve was used since that percentile reflects lower stages of the dry season when the risk of saltwater intrusion is increased. The score is calculated from the distance of the base conditions and alternatives to the two feet NGVD on the stage duration curve. Alternatives that equaled or exceeded the target scored 100% (no extra credit was given for exceeding the target).

Score = [(2 - Distance/2)] x 100 = % of meeting 2 foot target

The second scenario used the 50th percentile of the 1995 Base to evaluate performance since it represents approximately the midpoint between the wet and dry seasons and can be viewed as "average conditions" for the 1995 Base. The score reflects the percentile at which a base condition or alternative meets or exceeds the water level at the 50th percentile of the 1995 Base. Saltwater encroachment has occurred in the period of record and, therefore, exceeding the 50th percentile is considered an improvement but may not prevent further encroachment.

The base conditions and alternative scores were determined by averaging the scores for the two scenarios.

Flood Protection

Flood protection is one of the authorized purposes of the Restudy and will be evaluated and addressed during the detailed design phase of the study. Due to the grid size and type of model used during the Restudy alternative evaluation process, the performance measures available for the Lower East Coast Service Area are of limited value for direct evaluation of an alternative's affect upon flood protection. However, one performance indicator is applicable for the southern Miami-Dade County agricultural areas in Service Area 3, stage duration curves, and is used in this evaluation.

Urban Areas East of the Protective Levee in the Lower East Coast

Flood protection should be improved or at least not degraded by the selected plan. In many instances, the alternatives have reduced or eliminated adverse impacts to flood control associated with the components selected in the urban areas of the Lower East Coast. The alternatives provide additional water storage capacity through water preserve areas, reservoirs and aquifer storage and recovery, reducing the maximum stages in the canals during large rainfall events.

The risk of flooding may be decreased with the additional storage components; however, it is difficult to discern the improvements at this point in the alternative evaluation. The model used to evaluate the effects of the components on regional hydrology is not conducive for evaluating storm and flood events. The model uses a daily time step; storm and flood events occur within hours. One-performance indicator gauges the change in peak stages compared to the 1995 Base on a regional basis. The primary drawback of this performance indicator is that it does not distinguish between ground and surface water levels.

After the final plan is selected, this performance indicator will be used to identify areas of potential decreased flood protection coupled with site specific information regarding flood prone areas. Information regarding existing flood prone areas will be gathered from District and USACE staff familiar with the Lower East Coast supplemented with interviews with local government officials and other who have technical input. These areas will be mapped using the SFWMM grid cell boundaries and will be identified by the appropriate basin. These identified areas will undergo further evaluation in subsequent feasibility reports to determine what actions are necessary. In addition, portions of the study area outside of the boundaries of the SFWMM grid will need to be evaluated for flooding impacts through a separate process as well.

Agricultural Area along the L-31N

Performance Measure Used

One performance measure graphic was developed for use in six cells in the western areas of southern Miami-Dade County (Lower East Coast Service Area 3) to compare the relative performances of the different alternatives. It is labeled “end of the month stage duration curve 1983-1993”, and compares an 11-year target stage duration curve to the 31-year stage duration curves representing the performances of the bases and alternatives. The relative comparison of an 11-year curve to a 31-year curve appeared to be appropriate for use at the higher stages, but did not compare as well at the mid to lower stages.

Scoring Procedures

Because the comparisons between the curves are most appropriate at the higher stages, it was decided to use the point where the stage duration curves intersect with the “10 % time equaled or exceeded” line on the graphs. For each of the six indicator cells, the difference between where an alternative or base curve intersects the 10 % line and where the target curve intersects the 10 % line is measured (in tenths of a foot).

Only the increases in stages relative to the target are included in the matrix. The actual differences are shown in the first half of the matrix, and are used in the alternative scoring methodology described below. If an alternative performance falls below the target (performance is better than the target), a score of 0 is given. This is shown in the second half of the matrix. The values for all the cells are summed and normalized so the final scores range between 0 and 1.

A second scoring methodology that gives credit for flood protection above the target was used for comparison. In order to normalize the alternatives’ scores, five (5) was added to each sum so the final numbers were all positive. The resulting values are shown as an “alternative score”.

Interpretation of Results

Using the first scoring methodology, alternatives D13R and D13R4. performed equally. There is no measurable difference between the stage duration curves at the 10% line. The operational changes that were implemented in the C-111 basin in all alternatives are thought to be the reason for this result.

In looking at the second scoring methodology where credit is given for an increase in flood protection in some of the northern cells, alternatives D13R and D13R4 perform equally well. Since exceeding the target line is a “bonus” and it only occurred in some of the cells, it’s not recommended to base selection of a preferred alternative on these results. They are presented only for informational purposes.

Alternative D13R4 performed equally to Alternative D13R. There were no changes in operations in this area, so the performance did not change.

Table 10.

	R10 C25	R13 C25	R15 C26	R17 C27	R19 C27	R20 C27	
Difference in stage in tenths of a foot							**Totals**
95Base	1	1	2	-1	0	0	3
50Base	5	7	6	1	1	-2	18
Alt D13R	0	3	4	-3	-2	-3	-1
Alt D13R4	0	3	4	-3	-2	-3	-1
Increases in stage relative to the Target (tenths)							
95Base	1	1	2	0	0	0	4
50Base	5	7	6	1	1	0	20
Alt D13R	0	3	4	0	0	0	7
Alt D13R4	0	3	4	0	0	0	7
		SCORE			**Alternative Score**		
95Base		0.9				0.73	
50Base		0.3				0.23	
Alt D13R		0.8				0.87	
Alt D13R4		0.8				0.87	

Other Issues

Reductions in discharges to tidal waters proposed in D13R4: Reductions in discharges to tidal waters may cause both water quality and natural area impacts in response to the lowering of the flushing rates. With reduced fresh water discharges to tide, groundwater (typically low in dissolved oxygen) will contribute a larger portion of the base flow of these tidal bodies of water. Also, with reduced flushing rates the headwaters may be more inclined to be Abiologically conditioned with a potentially high incidence of undesirable algal blooms. Within Broward County the contrast between the tidal portion of the Middle River (C-13), which has good water quality, with the North Fork of New River (C-12), which has continuing unsolved water quality problems, may be a good example of the result of reduced fresh water flow. In addition, with a decrease in fresh water discharges the salinity regimes of the downstream tidal water will increase. Examples are the C-10 canal and Intracoastal Waterway between Port Everglades and Haulover Inlet. Both are prone to hypersaline conditions because of little or no fresh water discharges. Chloride levels as high as 22,000 mg/l have been recorded from dry season samples from the C-10 canal. Increased salinity regimes may have a profound change on the ecology of these waters and on the surrounding natural areas, such as cypress remnant stands on the New River, Cypress Creek and Middle River. In further evaluation of alternative D13R4, the operational schedule should consider minimizing these potential impacts.

Design of West Miami-Dade Reuse Facility in D13R4: The reconfiguration of discharge from the West Dade Reuse facility is of concern. Under D13R, discharge from the facility was proposed to either to the Bird Drive Recharge Area or the South Dade Conveyance System (SDCS). Pumping to the Bird Drive Recharge Area could provide an additional margin of water quality polishing prior to recharging the Biscayne aquifer and subsequently the West Wellfield (located just south of the Bird Drive Recharge Area) or to meeting demands elsewhere. Alternative D13R4 propose to move this water directly to the SDCS without temporary storage in a marsh system.

Interpretation of Scores for LECSAs

Summary: Based on the above interpretation of the performance measures, Alternatives D13R and D13R4 perform equally well and substantially improve water supplies compared to the 2050 Base for the Lower East Coast Service Area. The component changes between Alternative D13R and D13R4 do not negatively effect the LECSAs as modeled with the SFWMM. The one exception is a slight increase in water supply cutbacks in Service Area 2. The additional two months of cutbacks is not significant in itself, but do cause concern and warrants further investigation during the next phase of study.

North Palm Beach Service Area: The North Palm Beach Service Area scores very well, almost reaching the established goals in all alternatives. The scores for alternatives D13R and D13R4 reach 99%. The performance of the primary canals reaches their goals in all of the alternatives. The 1-in-10 level of service planning goal scores are met. The duration of cutbacks scores are very high as well and are just shy of reaching their goal. Compared to the 2050 Base, either of the proposed alternatives relying on alternative sources would provide additional water supplies to meet projected water demands, reduce the frequency and duration of water supply cutbacks and help abate saltwater intrusion in the North Palm Beach Service Area.

Service Area 1: Service Area 1 performs very well almost reaching the established goals in alternatives D13R and D13R4. The Scores for Alternative D13R and D13R4 reach 99%. The performance of the primary canals reaches their goals in both of the alternatives despite keeping more water west of the control structures to meet other demands further south in the system. The 1-in-10 level of service planning goal scores very high in all alternatives, above 95%. The duration of cutbacks scores are very high as well and are just shy of reaching their goal. Compared to the 2050 Base, either of the proposed alternatives relying on alternative sources would provide additional water supplies to meet projected water demands, reduce the frequency and duration of water supply cutbacks and help abate saltwater intrusion in Service Area 1.

Service Area 2: Service Area 2 performs well in alternatives D13R and D13R4. The average scores for these two alternatives are 93% for D13R4 and 96%

for D13R. This compares very favorably to the 2050 Base, which scores only 54% for Service Area 2. The ability to maintain primary coastal canals performed well in both of the alternatives. It is just shy of reaching its goal despite keeping more water west of the control structures to meet other demands further south in the system. The 1-in-10 level of service planning goal score for all of the alternatives is significantly higher than the 2050 Base, which has cutbacks almost every year, scoring a dismal 4%. Although Alternative D13R4 scores slightly lower than D13R, the actual difference is two more months of cutbacks over the period of record in Alternative D13R4. This is reflected in the duration performance measure. The duration of cutbacks scores improve significantly when compared to the 2050 Base. Compared to the 2050 Base, either of the proposed alternatives would provide additional water supplies to meet projected water demands, reduce the frequency and duration of water supply cutbacks and help abate saltwater intrusion in Service Area 2.

Service Area 3: In Service Area 3, the overall performance improves in alternatives D13R and D13R4 compared to the 2050 Base. The score for these two alternatives is 92%. This compares favorably to the 2050 Base, which scores only 70% for Service Area 3. Both of the alternatives performed well in maintaining the primary coastal canals. The other canals in southern Miami-Dade County score well, but fail to perform well enough to reach their targets. Both of the alternatives' perform equally well to improve meeting the 1-in-10 level of service planning goal when compared to the 2050 Base. The duration of cutbacks scores very high for both alternatives, with Alternatives D13R and D13R4 performing equally well. Except for maintaining water levels in southern Miami-Dade canals, the performance of both of the alternatives as evaluated in the matrix exceeds the performance of the 2050 Base.

Table 11
Subregion: Lower East Service Area*

Performance Measure	1995 Base	2050 Base	Alt D13R	Alt D13R
Ability to Meet 1-10 water supply planning goal for NPB SA	70%	56%	100%	100%
Ability to Maintain Primary Coastal Canals at or above Salt-water Intrusion Criteria in NPB SA	100%	100%	100%	100%
% of Months Not in Water Supply Cutbacks in NPB SA	87%	81%	96%	96%
North Palm Beach Service Area Average Score	**86%**	**79%**	**99%**	**99%**

Performance Measure	1995 Base	2050 Base	Alt D13R	Alt D13R
Ability to Meet 1-10 water supply planning goal for SA 1	63%	40%	100%	100%
Ability to Maintain Primary Coastal Canals at or above Salt-water Intrusion Criteria in SA 1	100%	100%	100%	100%
% of Months Not in Water Supply Cutbacks in SA 1	87%	76%	96%	96%
Service Area 1 Average Score	**83%**	**72%**	**99%**	**99%**
Ability to Meet 1-10 water supply planning goal for SA 2	26%	4%	93%	85%
Ability to Maintain Primary Coastal Canals at or above Salt-water Intrusion Criteria in SA 2	94%	95%	100%	100%
% of Months Not in Water Supply Cutbacks in SA 2	75%	62%	95%	94%
Service Area 2 Average Score	**65%**	**54%**	**96%**	**93%**
Ability to Meet 1-10 water supply planning goal for SA 3	78%	56%	95%	95%
Ability to Maintain Primary Coastal Canals at or above Salt-water Intrusion Criteria in SA 3	77%	89%	100%	99%
Ability Maintain Water Levels in South Dade Canals**	58%	56%	77%	77%
% of Months Not in Water Supply Cutbacks in SA 3	89%	79%	95%	95%
Service Area 3 Average Score	**76%**	**70%**	**92%**	**92%**
Average Weighted Score	**77%**	**69%**	**96%**	**96%**

* Flood protection not evaluated in this matrix

Biscayne Bay

Biscayne Bay Flows

Flows to South and Central Biscayne Bay increased and exceeded targets, but dry season flows to Snake Creek were less than D13R and less than target, and dry season flows to the Miami River decreased relative to D13R.

*Snake Creek: D13R4 flows are very slightly reduced relative to D13R in the wet season, but are reduced by 23% relative to D13R in the dry season. Flows under D13R4 exceed the target in the wet season but are only 22% of target for the dry season (28% of target for D13R).

North Bay: D13R4 flows are approximately equal to 2050 Base and D13R flows in both wet and dry seasons, and are slightly smaller than 1995 Base flows.

*Miami River: D13R4 flows are 14% higher in the wet season but 1% lower in the dry season than D13R. Since no targets were specifically set for the Miami River, flow volumes to this region should be considered interim until such time as a thorough evaluation is conducted of hydrodynamic and water quality issues in this portion of Biscayne Bay.

Central Bay: D13R4 flows are higher than the target, D13R, 1995 Base and 2050 Base. Both wet season and dry season targets would be met without any input of South Miami Dade coastal reuse water.

South Bay: D13R4 flows are higher than the target, D13R, 1995 Base and 2050 Base. The dry season target would be met without any input of South Miami Dade coastal reuse water.

Card and Barnes Sounds and Manatee Bay: While no specific performance measures were prepared concerning flows to southernmost Biscayne Bay, this area is expected to be seriously deficient in freshwater inflow relative to needs, once current C111 plans are implemented, and the objective is to replace canal discharge with overland flow through adjacent coastal wetlands. Expected improvements in overland flow can be estimated based on water levels in the wetlands (i.e., the Model Lands). While D13R4 provides slightly higher water levels in the coastal wetlands, compared to D13R, this is not likely to be enough to overcome the serious deficiency in consistent freshwater flow to that part of the bay.

Target and Model-Estimated Mean Annual Surface Flows to Biscayne Bay (in thousands of acre feet/year) under the 1995 base condition and Alternatives D13R and D13R4 (values for Central Bay and South Bay are calculated without coastal reuse water inputs).

Table 12. Surface Water Flows to Biscayne Bay

	Wet season				Dry season			
Region	**Target**	**95Base**	**D13R**	**D13R4**	**Target**	**95Base**	**D13R**	**D13R4**
Snake Creek	67	121	79	78	93	51	26	20
North Bay		99	97	97		41	38	37
Miami River		132	43	49		60	18	17
Central Bay	161	161	142	170	83	64	78	104
South Bay	158	158	136	149	68	52	56	69

Biscayne Bay Ground Water

North Biscayne Bay Ground Water 1 Stage Duration Curve: There is minimal difference between D13R4 and D13R.

North Biscayne Bay Ground Water 2 Stage Duration Curve: There is minimal difference between D13R4 and D13R.

Central Biscayne Bay Ground Water Stage Duration Curve: There is minimal difference between D13R4 and D13R.

South Biscayne Bay Ground Water Stage Duration Curve: There is minimal difference between D13R4 and D13R.

C-111/Model Lands Basin

Model Lands South (IR 5) Weekly Stage Duration Curve: D13R4 levels are approximately equal to D13R except at the driest 20% of the record, where D13R4 shows an improvement over D13R.

C-111 Perrine Marl Marsh (IR 4) Stage Duration Curve, Model Lands North Weekly (IR 6) Stage Duration Curve, North C-111 (IR 47) Stage Duration Curve: D13R4 water levels show a minor improvement over those in D13R.

Table 13. C-111/Model Lands Performance

Indicator Region Average Score	**95Base**	**2050Base**	**D13R**	**D13R4**
Indicator Region 4 (C-111 Perrine Marl Marsh)	0.640	0.555	0.795	0.827
Indicator Region 5 (Model Lands South)	0.448	0.484	0.864	0.877
Indicator Region 6 (Model Lands North)	0.534	0.546	0.636	0.642
Indicator Region 47 (North C-111)	0.564	0.653	0.800	0.826
Total Regional Average Score	0.547	0.559	0.774	0.793

Big Cypress

AREA/SUBREGION/INDICATOR REGIONS

Different portions of the Big Cypress subregion are used in the different matrix equations.

PERFORMANCE MEASURES

1. Mean NSM Hydroperiod Matches for North Big Cypress National Preserve for the 31 year simulation

2. Mean NSM Hydroperiod Matches for South Big Cypress National Preserve for the 31 year simulation

3. Normalized Weekly Stage Duration Curves for Indicator Regions 13, 31, 36-40, 45, and 42-43

4. Average Annual Overland Flows toward Gulf of Mexico from Big Cypress National Preserve for the 31 year simulation

5. Inundation Duration Summary for Indicator Regions: Average Flood Duration

Scoring Explanation

All of the scores are relative to NSM conditions in the Big Cypress.

A = percent of North Big Cypress National Preserve that matches NSM (PM #1). This provides a spatial measure of one of the more impacted portions of the Big Cypress that lies along its northern border. Impacts are due primarily to agricultural development and its associated canals upstream (north) of this area. In addition, there may be some model boundary problems in this area, possibly related to the fact that the area to the north is included in the Natural System Model, but not the South Florida Water Management Model.

B = percent of South Big Cypress National Preserve that matches NSM (PM #2). This provides a spatial measure of the relatively unimpacted portion of the Big Cypress. This area is dominated by rainfall inputs, and as a result, exhibits few effects of hydrologic alterations beyond its boundaries. Hydrologic effects of the Restudy alternatives occur primarily along the Big Cypress boundary with the Everglades.

C (for individual Indicator Regions) = 1 - {absolute number [(percent of time flooded for NSM) - (percent of time flooded for Base or Alternative)] /100} (PM #3). This provides a measure of deviation from NSM hydroperiod for an Indicator Region. This deviation is almost always a reduction in hydroperiod. The selected Indicator Regions are all in the eastern portion of the Big Cypress near its border with the Everglades, since there is little effect of any of the Alternatives on the western portion of the Big Cypress. Initially all of the Indicator Regions were evaluated separately (Table 14).

Equations were developed to combine some Indicator Regions in a simple additive form because of different influences in different areas. Indicator Regions 31, 36-40, and 45 were combined since they are all probably influenced by flows in the vicinity of South L-28 (South Big Cypress). Indicator Regions 42 and 43 were combined since they are both in the area affected by the L-28 Interceptor and the Western Feeder Canal (North Big Cypress). Indicator Region 13 was not combined with any other Indicator Regions (Southeast Big Cypress).

D_n(for individual Indicator Regions) = 1 – absolute number [(maximum deviation from NSM hydrograph) / (maximum range of NSM water level fluctuation)] (PM #3). This provides a measure how much water levels have been altered from NSM conditions as a function of the NSM range of fluctuation for an Indicator Region. A certain degree of deviation in an area with a large natural fluctuation would be less significant than in an area with a small natural fluctuation. Typically, the greatest deviation occurs when the water table is declining through the first foot or two below the ground surface, it is smallest at its lowest point on the hydrograph, and it is relatively small when the water table is above ground. The selected Indicator Regions are all in the eastern portion of the Big Cypress near its border with the Everglades, since there is little effect of any of the Alternatives on the western portion of the Big Cypress. Initially all of the Indicator Regions were evaluated separately (Table 14).

Equations were developed to combine some Indicator Regions in a simple additive form because of different influences in different areas (Table 14). Indicator Regions 31, 36-40, and 45 were combined since they are all probably influenced by flows in the vicinity of South L-28 (South Big Cypress). Indicator Regions 42 and 43 were combined since they are both in the area affected by the L-28 Interceptor and the Western Feeder Canal (North Big Cypress). Indicator Region 13 was not combined with any other Indicator Regions (Southeast Big Cypress).

G = 1 – absolute number [(deviation of average flood duration from NSM average flood duration) / (NSM average flood duration)] (PM #5). This provides a measure of deviation from NSM for average duration of individual flooding events for an Indicator Region. This deviation is usually a reduction in the duration of inundation. The selected Indicator Regions are all in the eastern portion of the Big Cypress near its border with the Everglades, since there is little effect of any of the Alternatives on the western portion of the Big Cypress. Initially all of the Indicator Regions were evaluated separately (Table 14).

Equations were developed to combine some Indicator Regions in a simple additive form because of different influences in different areas (Table 14). Indicator Regions 31, 36-40, and 45 were combined since they are all probably influenced by flows in the vicinity of South L-28 (South Big Cypress). Indicator Regions 42 and 43 were combined since they are both in the area affected by the L-28 Interceptor and the Western Feeder Canal (North Big Cypress). Indicator Region 13 was not combined with any other Indicator Regions (Southeast Big Cypress).

E_w = 1 – absolute number [(deviation of wet season flows from NSM flows) / (NSM wet season flows)] (PM #4)

E_d = 1 – absolute number [(deviation of dry season flows from NSM flows) / (NSM dry season flows)] (PM #4)

Total flows during the wet and dry season provide another way of expressing hydrologic conditions and how they change in response to proposed Alternatives in particular portions of the Big Cypress. The flow cross-sections evaluated included the Eastern Big Cypress and Lostman's. Initially the flow cross-sections were evaluated separately by wet and dry season (Table 14).

I have developed simple additive equations for each flow cross-section to combine the wet and dry season information (Table 14).

Summary Equations

I subsequently developed summary equations for major geographic regions of the Big Cypress that were distinct in terms of their response to the various Restudy alternatives (Table 14). These major areas were: **North Big Cypress**, which was only affected by Alternatives C and D where the L-28 Interceptor canal and levee system were modified; **South Big Cypress**, which was affected primarily by alterations to the south end of the L-28 canal and levee and in the adjacent Water Conservation Area 3A; and **Southeast Big Cypress**, which being on the border between the Everglades and southeast portion of the Big Cypress Swamp, is affected by the numerous alterations to the Everglades.

For each of these geographic areas, a simple additive equation was developed to combine variables C_n, D_n and G_n for the same Indicator Region(s) to summarize information on deviations in hydroperiod, water depth, and average flood event duration in these areas. In North Big Cypress, I included variable A in this simple additive equation. In South Big Cypress, I included variable B and variable E for flows across the Eastern Big Cypress along Tamiami Trail. In Southeast Big Cypress, I included variable E for flows across the Lostman's cross-section south of Tamiami Trail.

I also developed a single equation that combined the three Big Cypress regions.

Discussion

Scores were developed separately for each variable in each Indicator Region and for each cross-section or boundary (Table 14). I then combined them in a stepwise fashion, as described above, so that the AET would be able to comment on what is gained and lost as each Performance Measure was combined with others. Originally I developed two sets (with or without flows) of the three summarizing equations, with the goal of reducing all of the variables to three scores, one for the North Big Cypress, one for the South Big Cypress, and one for the southeastern Big Cypress. I ultimately produced two whole Big Cypress equations, again depending on whether flow parameters are used or not in the equations.

As a result of discussions at the late May AET meetings, I decided to focus on using the information contained in the three geographically separate equations that included the flow cross-section information (Table 14). Each of these three summary rows of the matrix provided distinctive information relevant to understanding influences that each of the Alternatives had on the Big Cypress.

All of the effects on the North Big Cypress occurred in Alternatives C and D, and were retained in D13, D13R, and D13R4. The effects resulted from filling the L-28 Interceptor Canal and removing its western levee, creating openings for water to move south along the Western Feeder Canal, and replacing S-190 with a pump station to maintain upstream drainage. This scenario also required some sort of water treatment capability to assure that all water moving south and southwest from the upstream canal system would provide only clean water. These components converted an area about two cells wide for most of the length of the L-28 Interceptor along its western side to approximately NSM conditions. Because the locations of the restored cells and the Indicator Regions available in the vicinity were not the same, the low matrix scores did not adequately reflect the high degree of restoration that actually occurred in portions of this area from the implementation of these components.

In the South Big Cypress, the most significant changes occurred in Alternative D, with the removal of the L-28 Tieback Levee. With this structure removed, hydrologic conditions showed almost complete restoration to NSM conditions, including restored hydroperiods and increased flows across the eastern portion of the Big Cypress. The model results for D13, D13R, and D13R4 were almost identical to one another, and (delete "both") showed generally small but distinct increased deviations from NSM (drier than NSM) as compared to Alternative D. The matrix values for D13 were almost identical to the 95 Base conditions in this area, but were higher (wetter) than for the 2050 Base. When looking at the hydrologic responses to these alternatives for individual Performance Measures and Indicator Regions, the geographic area where the deviations were greatest was in the vicinity and downstream of the jetport. We determined that the jetport was not modeled in the SFWMM, so it is not the cause of the problem. The somewhat poorer conditions in South Big Cypress relative to NSM in the D13 scenarios seemed to be associated with the movement of water to the east rather the west as occurred under NSM conditions in the vicinity of the Jetport. This change in flow direction appeared to result from a slightly lower-than-NSM topography that currently exists in this area in the SFWMM. It did not occur prior to Alternative D13 because of the presence of L-28.

In the southeastern Big Cypress along its border with the Everglades and below Tamiami Trail, the most significant changes occurred in Alternative B, when the L-28 and L-29 levees and canals were removed. According to the model, there were larger areas showing reduced hydroperiods and the reductions in hydroperiods and flows were greater than in Alternatives A, C, or D, all of which were close to NSM condition. In Alternative C, the L-28 and only the western portion of L-29 were restored, which was sufficient to return conditions in this area close to NSM. The removal of the L-28 Tieback in Alternative D did not seem to affect this portion of the Big Cypress. Alternatives D13, D13R, and D13R4 produced generally small and variable responses among the various Performance Measures, resulting in an overall minor difference in the summary matrix value for this portion of the Big Cypress.

Summary

The combination of components in Alternative D produced the greatest benefits in terms of restoring the largest amount of area in the Big Cypress to approximately NSM conditions. It also seems that several of the most beneficial components could be implemented in any of the Alternatives, since they operate pretty much independently from the rest of the Everglades ecosystem. This would be the situation for the L-28 Interceptor and L-28 Tieback components. Changes to the L-28 South and L-29 have more extensive and complex interactions with other parts of the Everglades.

In using the colors and grades to differentiate restoration success as indicated by the various Performance Measures for each the Bases and Alternatives (A-D, D13, D13R, D13R4), I used matrix value ranges of 86-100 (green, grade A), 71-85 (yellow, grade B), and <71 (red, grade C). These ranges generally seemed to do a reasonably good job of sorting restoration gains and losses for the Big Cypress region that were associated with each of the Alternatives. The only portion of the region where these results could be misinterpreted is the North Big Cypress. The portion of this area influenced by the L-28 Interceptor system should be included in the green grade A category in Alternatives C, D, D13, D13R, and D13R4. The portion further west still shows severe hydrologic impacts, even in these latter Alternatives. However, based on a helicopter overflight of the area to assess its condition and our understanding of how the models are operating in this area, it is very likely that these impacts are merely the result of modeling problems, and in reality are much less severe than suggested by the SFWMM.

There were no significant changes in the Big Cypress performance measures from alternative D13R. North Big Cypress has not changed since Alternative C when the L-28 Interceptor canal and its west levee were removed and water from the upstream North and West Feeder canals was distributed as sheet flow across the northeastern Big Cypress. Southeast Big Cypress has maintained fairly constant conditions since Alternative A, with the exception of Alternative B, which produced the most adverse effects of Alternatives A-D and the D13s. Hydrologic conditions in the South Big Cypress were closest to NSM under Alternative D and were close to 1995 Base conditions and slightly better than the 2050 Base in the D13R scenarios. The somewhat poorer conditions in South Big Cypress relative to NSM in the D13 scenarios seemed to be associated with the movement of water to the east rather than the west as occurred under NSM conditions in the vicinity of the Jetport. This change in flow direction appeared to result from a slightly lower-than-NSM topography that currently exists in this area in the SFWMM. It did not occur prior to Alternative D13 because of the presence of L-28.

Table 14. Big Cypress Basin

VARIABLE	NSM	1995	2050	ALT A	ALT B	ALT C	ALT D	D13R	D13R4
Percent of North Big Cypress that Matches NSM / 100									
A	1.00	0.47	0.46	0.46	0.49	0.64	0.64	0.64	0.64
Percent of South Big Cypress that Matches NSM / 100									
B	1.00	0.99	0.97	0.97	0.92	0.99	1.00	0.99	0.97
Reduction in Percent of Time Inundated from NSM Condition									
C-13	1.00	0.99	0.93	0.99	0.95	0.99	0.99	1.00	1.00
C-31	1.00	0.90	0.90	0.90	0.91	0.94	0.94	0.94	0.94
C-36	1.00	0.94	0.92	0.92	0.91	0.95	1.00	0.94	0.94
C-37	1.00	0.93	0.91	0.91	0.91	0.94	0.99	0.95	0.95
C-38	1.00	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98
C-40	1.00	0.97	0.97	0.96	0.96	0.97	1.00	0.98	0.98
C-45	1.00	0.99	0.97	0.97	0.98	0.99	0.99	0.99	0.99
C-42	1.00	0.81	0.81	0.81	0.81	0.92	0.92	0.92	0.92
C-43	1.00	0.35	0.34	0.34	0.34	0.63	0.63	0.63	0.63
Maximum Deviation from NSM Stage Duration Curve									
D-13	1.00	0.95	0.92	0.98	0.95	0.96	0.97	0.99	0.99
D-31	1.00	0.94	0.94	0.94	0.95	0.96	0.96	0.96	0.96
D-36	1.00	0.97	0.95	0.95	0.95	0.96	0.98	0.96	0.96
D-37	1.00	0.95	0.95	0.95	0.95	0.96	0.99	0.96	0.96
D-38	1.00	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
D-39	1.00	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98
D-40	1.00	0.98	0.98	0.98	0.96	0.98	0.99	0.98	0.98
D-45	1.00	0.98	0.98	0.97	0.98	0.98	0.99	0.98	0.98
D-42	1.00	0.89	0.89	0.89	0.89	0.94	0.94	0.94	0.94
D-43	1.00	0.51	0.50	0.50	0.51	0.57	0.57	0.57	0.57
Percent Change in Flow from NSM Condition / 100									
Ew-east BC	1.00	0.76	0.72	0.72	0.73	0.80	0.99	0.84	0.83
Ed-east BC	1.00	0.65	0.55	0.45	0.50	0.53	0.78	0.65	0.60
Ew-Lostman's	1.00	0.60	0.68	0.93	0.79	0.98	0.96	0.97	0.95
Ed-Lostman's	1.00	0.63	0.42	0.91	0.63	0.91	0.88	0.98	0.93
Average Flood Duration									
G-13	1.00	0.93	0.89	0.96	0.86	1.00	1.00	0.86	0.93
G-31	1.00	0.93	0.93	0.93	0.93	0.93	1.00	1.00	1.00
G-36	1.00	0.89	0.78	0.72	0.78	0.83	0.94	0.83	0.83
G-37	1.00	0.82	0.71	0.71	0.71	0.76	0.94	0.82	0.82
G-38	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
G-39	1.00	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
G-40	1.00	0.91	0.87	0.83	0.87	0.91	1.00	0.96	0.96
G-45	1.00	0.91	0.91	0.91	0.91	0.91	1.00	0.91	0.91
G-42	1.00	0.55	0.55	0.55	0.55	0.73	0.73	0.73	0.73
G-43	1.00	0.13	0.13	0.13	0.13	0.45	0.45	0.45	0.45

VARIABLE	NSM	1995	2050	ALT A	ALT B	ALT C	ALT D	D13R	D13R4
NORTH BIG CYPRESS									
A	1.00	0.47	0.46	0.46	0.49	0.64	0.64	0.64	0.64
Reduction in Percent of Time Inundated from NSM Condition									
C42-C43	1.00	0.58	0.58	0.58	0.58	0.78	0.78	0.78	0.78
Maximum Deviation from NSM Stage Duration Curve									
D42-D43	1.00	0.70	0.70	0.70	0.70	0.76	0.76	0.76	0.76
Average Flood Duration									
G42-G43	1.00	0.34	0.34	0.34	0.34	0.59	0.59	0.59	0.59
Summary - North Big Cypress									
	1.00	0.52	0.52	0.52	0.53	0.69	0.69	0.69	0.69
SOUTH BIG CYPRESS									
Percent of South Big Cypress that Matches NSM / 100									
B	1.00	0.99	0.97	0.97	0.92	0.99	1.00	0.99	0.97
Reduction in Percent of Time Inundated from NSM Condition									
C31,C36-C40	1.00	0.95	0.94	0.94	0.94	0.96	0.98	0.96	0.96
Maximum Deviation from NSM Stage Duration Curve									
D31, D36-D40	1.00	0.97	0.96	0.96	0.96	0.97	0.98	0.97	0.97
Average Flood Duration									
G31, G36-G40	1.00	0.89	0.85	0.84	0.85	0.87	0.95	0.90	0.90
Percent Change in Flow from NSM Condition / 100									
(Ew+Ed)/2 East BC	1.00	0.70	0.63	0.58	0.62	0.66	0.88	0.75	0.72
Summary - South Big Cypress									
	1.00	0.90	0.87	0.86	0.86	0.89	0.96	0.91	0.90

SOUTHEAST BIG CYPRESS									
Reduction in Percent of Time Inundated from NSM Condition									
C-13	1.00	0.99	0.93	0.99	0.95	0.99	0.99	1.00	1.00
Maximum Deviation from NSM Stage Duration Curve									
D-13	1.00	0.95	0.92	0.98	0.95	0.96	0.97	0.99	0.99
Average Flood Duration									
G-13	1.00	0.93	0.89	0.96	0.86	1.00	1.00	0.86	0.93
Percent Change in Flow from NSM Condition / 100									
(Ew+Ed)/2 Lostman's	1.00	0.61	0.55	0.92	0.71	0.94	0.92	0.98	0.94
Summary - Southeast Big Cypress									
	1.00	0.87	0.82	0.96	0.87	0.97	0.97	0.96	0.97

ATLSS / Threatened and Endangered / Keystone Species

Cape Sable seaside sparrow

For the western subpopulation, inspection of performance measure graphics for indicator region 46 might suggest a negligible difference in effects to sparrows for the D13R4 and D13R alternatives. However, ATLSS individual-based modeling for this subpopulation is relatively sensitive to what appear to be minor shifts in the stage duration curves. A small change in the timing and duration of flooding can have a pronounced effect on population projections in the ATLSS model. ATLSS modeling results for D13R4 are similar to D13R, but show a greater tendency for subpopulation numbers to drop below 500 individuals. In addition, D13R4 results are only a slight improvement over 2050 Base conditions according to the ATLSS results. The Service believes that these results indicate that there is potential for significant adverse effects to the western subpopulation of the Cape Sable seaside sparrow within the range of flexibility demonstrated for alternative D13R. As a result, any Restudy implementation effort that proceeds toward the "wetter" range of possible D13R scenarios must exercise extreme caution with regards to possible effects on the sparrow's western subpopulation. ATLSS individual modeling for these subpopulations provides a far more detailed and sophisticated analysis of expected effects on sparrow demographics than do the indicator region graphics. Therefore, the U.S. Fish and Wildlife Service believes that the ATLSS modeling provides the best currently available scientific information for assessing effects to the endangered Cape Sable seaside sparrow.

For the eastern subpopulations C, E and F, D13R4 hydroperiods are significantly increased as compared to D13R and are slightly longer than NSM. While it is difficult to predict what effects these longer-than-NSM hydroperiods might have on the eastern marl prairie habitats, adverse effects to sparrow habitat have been documented as a result of increased hydroperiods resulting from S332 pumping in subpopulation C. Careful monitoring will be necessary if/when such a scenario is implemented. Overall, D13R4 should provide improved habitat conditions for the sparrow as compared to 2050 Base.

Wood stork

Based on John Ogden's revised stork performance measure (Table 15), alternative D13R4 provides significantly improved conditions for nesting in the historically important Shark Slough and Taylor Slough mangrove fringe as compared to D13R and both base cases.

Crocodile and Manatee

Based on the Shark and Taylor Slough flow lines, and P-33 salinity predictions for Florida Bay, D13R4 should provide increased habitat suitability for crocodiles and manatees as compared to D13R and both base cases.

Snail kite

ATLSS snail kite foraging index results show that foraging condition values for both D13R4 and 2050 Base are high across large parts of the remaining Everglades under very wet conditions. However, under D13R4, water levels are too high in parts of each of the WCAs to provide effective snail kite foraging. In addition, losses of snail kite nesting substrate in these areas, particularly in WCA-3B, would be expected during high water conditions produced by D13R4. Under very dry conditions, D13R4 provides slightly higher foraging condition values than 2050 Base in WCA-1, WCA-3B and the periphery of Shark Slough. Overall, D13R4 results are similar to those for D13R, except for reduced foraging and nesting habitat under very wet D13R4 conditions.

Table 15. Summary of wood stork performance measure elements.

Performance Element	NSM	95 Base	2050 Base	D13R	D13R4
IR 9 innundation duration	176	75	98	156	174
IR 10 innundation duration	321	93	108	398	265
IR 9 ratio to NSM	1.0	0.43	0.56	0.89	0.99
IR 10 ratio to NSM	1.0	0.29	0.34	1.24 (0.76)*	0.83
IR average	1.0	0.36	0.45	1.07	0.91
Taylor Slough flow volume	83	102	69	74	82
Shark Slough flow volume	1519	702	826	1097	1255
TS ratio to NSM	1.0	1.23	0.83	0.89	0.99
SS ratio to NSM	1.0	0.46	0.54	0.72	0.83
Flow average	1.0	0.85	0.69	0.81	0.91
Weighted score		**0.51**	**0.53**	**0.79**	**0.89**

* reflects correction for % less than NSM, allowing correct calculation of weighted score.